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THE EQUATORIAL IONOSPHERE DYNAMICS DURING 10 MARCH 1998 STORM

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Abstract

Variations of the virtual ionosphere height and critical frequency foF2 for Cebu Island, Manila and Jicamarca are compared with interplanetary magnetic field behavior. It is shown that these variations are determined to a significant degree by the direction of the Bz-component of the interplanetary magnetic field. The ionospheric heights and foF2 during the northward IMF Bz (the quiet period on 7 March 1998) and southward IMF Bz (the main phase of 10 March 1998 magnetic storm) at Cebu and Manila are quite different. The distinction in the heights for quiet and disturbed periods can reach 100 km and greater. The critical frequency foF2 is noticeably lower during southward Bz IMF. These phenomena can be mostly explained within the framework of the solar wind – magnetosphere – ionosphere coupling. We show that the field-aligned currents serve as a coupling agent, which provides a relationship between the auroral and equatorial ionosphere.

Introduction

Intense ionospheric currents during geomagnetic storms change the quiet ionosphere, the short-term variations of the ionospheric parameters being observed. Under these conditions the critical frequencies foF2, virtual heights h'F, drift velocities and other ionospheric characteristics are mainly defined by the state of the solar wind flowing around the Earth's magnetosphere. Numerous works present experimental and theoretical relations found between the conditions in the solar wind and auroral ionosphere. The studies of Zmuda and Armstrong (1974), Iijima and Potemra (1978), Foster et al. (1989) and other authors lead to the conclusion that the field-aligned currents provide a major interconnection between the magnetosphere and ionosphere. As shown by Rastogi and Patel (1978), and Fejer et al. (1979), during geomagnetic disturbances interplanetary magnetic field effect is pronounced in the equatorial ionosphere too. The authors explain the short-term equatorial ionospheric variations by action of auroral sources. However, the equatorial ionosphere was assumed to be free of the field-aligned current effect. From the modern point of view, the equatorial ionosphere characteristics become highly subject to the action of the field-aligned currents. Zakharov (1989), Denisenko and Zamai (1992), Kikuchi et al (1996), using geomagnetic data, and Sizova and Pudovkin (2000), based on ionospheric data, showed that the electric fields from the FAC can penetrate to the equatorial ionosphere and explain the equatorial electric field variations.

Complicated nature of auroral and equatorial ionosphere relationship during magnetic disturbances can not account for some aspects of experimental data and models. To clear up the nature of short-term equatorial ionospheric variations further investigations of ionospheric characteristics are required. The critical frequency foF2 and virtual heights h'F observed by an ionosonde become a good indicator of real layer heights and electron concentration to provide information about the equatorial ionosphere dynamics. From the practical point of view, the relationships between the solar wind and the ionosphere parameters can be used for forecasting.

We continue treatment of the above mentioned problem in order to explain the critical frequency foF2 and virtual height changes at the equator during magnetic storms in terms of the auroral field-aligned current effect.

Data analysis

Variations of the critical frequency foF2 and virtual ionosphere height h'F for Cebu Island (124 deg. E, 10.3 deg. N; 2.4 deg.N in diplatitude), Manila (121 deg.E, 14.6 deg. N, 7.3 deg. N in diplatitude) and Jicamarca (76.9 deg. W, 11.9 deg. S, -0.7 deg. S in diplatitude) have been considered. On 10 March a moderate geomagnetic storm with Dst = -120 nT occurred. It was triggered by the positive solar wind electric field persisting from 1500 to 1930 UT. During this period the IMF Bz reached –18 nT and solar wind velocity was V = 550 km/s. Let us examine the foF2 and h'F data during the main phase of the geomagnetic storm on 10 March 1998 and compare them with the quiet day data on 7 March 1998. Figure 1 shows these data from 1200 to 2400 UT. For convenience of comparison of the ionospheric data with interplanetary and geomagnetic ones Universal Time (UT) is used in the Figures. Local Time (LT) for Manila and Cebu is LT = UT + 8 h, for Jicamarca LT = UT – 5h. The right panel of Fig. 1 depicts some typical samples of quiet foF2 and h'F variations when the Bz- component of the IMF is around zero. It should be noted that the equatorial

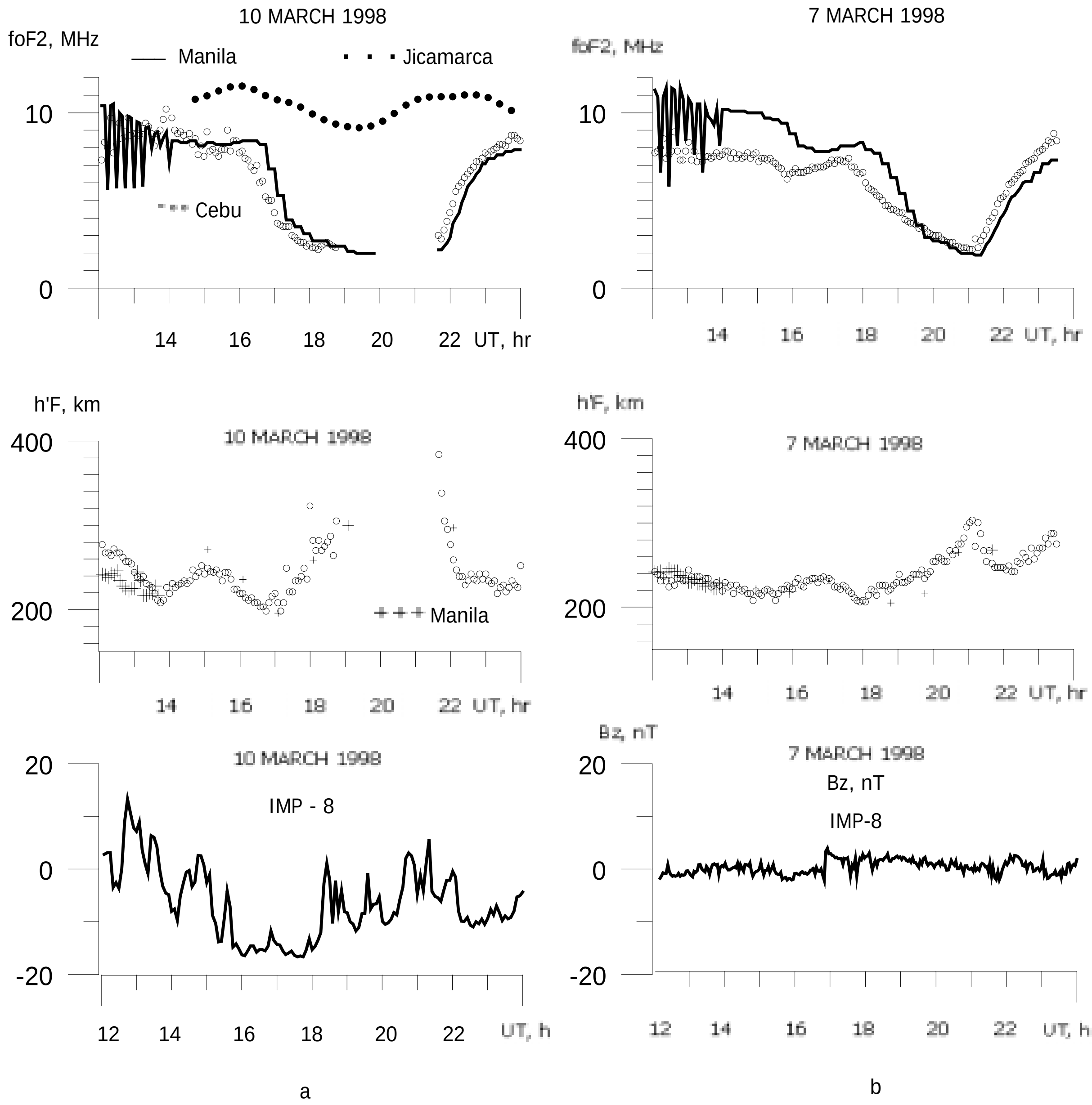

Fig.1 Variations of the critical frequency foF2 at Cebu (circles) and Manila (solid line), ionospheric heights h'F at Cebu (circles) and Manila (crosses), foF2 at Jicamarca (dots) and IMF Bz component (solid lines) on 7 (panel b) and 10 (panel a) March 1998.

ionosphere varies in the same manner at Cebu and Manila. But one can see significant distinctions between the values of the ionospheric characteristics on the two days of interest. The difference in the heights h'F during quiet and disturbed periods reaches 100 km and more. For example, at 18 UT on 7 March and 10 March the heights h'F at Cebu / Manila are 200 km and 300 km, respectively; the foF2 at these stations are around 8 MHz and 2 MHz, correspondingly. The virtual height h'F at Cebu dropped from 390 km to 220 km near 22 UT. During the main phase of the geomagnetic storm the foF2 began to subside and h'F began to increase at the two stations at 1630 UT, whereas for the quiet day it occurred at 1800 UT. A time delay between the Bz IMF reaching its minimum (the IMP-8 data on the bottom panel of Fig. 1, left) and onset of the equatorial ionospheric and auroral disturbances was around 40 minute. We have also analyzed 210^0 Magnetic Meridian data (STELAB, Nagoya University). Daily magnetograms from the high latitudes on 7 and 10 March 1998 are presented in Fig. 2 (right panel). During the quiet day when the IMF Bz was around zero, the westward polar electrojet was absent in the auroral region, as seen by Kotelny (KTN), Tixie (TIK), Chokurdakh (CHD), Zyryanka (ZYK) and Magadan (MGD) stations. On 10 March 1998 a strong westward electrojet was observed. It was associated with the IMF Bz turning to the south. This resulted in h'F rising and foF2 dropping at Cebu and Manila correlated with high latitude geomagnetic disturbances. As seen from Fig.1, the foF2 variations correlated with the Bz IMF were observed at Jicamarca for the same UT.

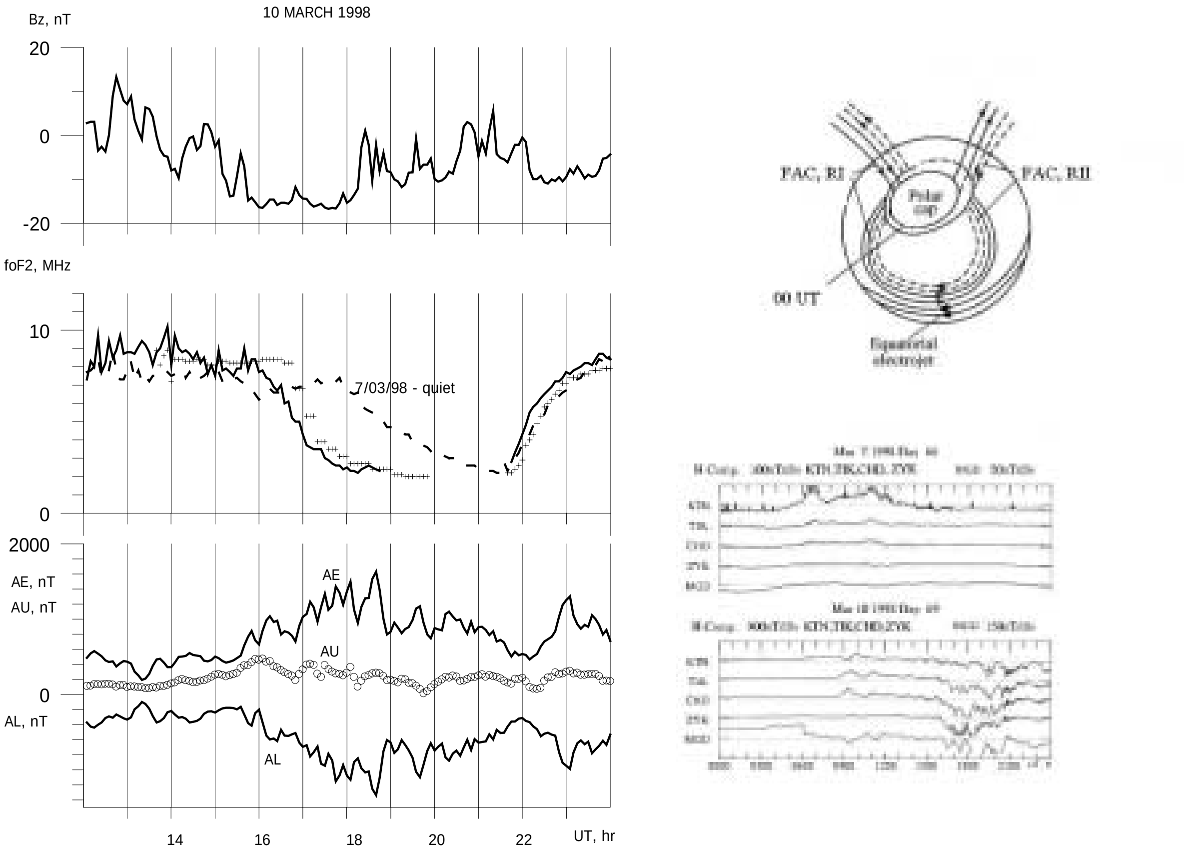

Fig. 2. The left panel: variations of the Bz IMF, critical frequency foF2 at Cebu (solid lines), at Manila (crosses) AL, AE, AU during the main phase of 10 March 1998 geomagnetic storm. The critical frequency foF2 during the quiet day at Cebu is depicted by the dashed line. The right panel: (top) the model of the Region I and Region II field-aligned currents closing across the equatorial ionosphere in the nighttime and (bottom) magnetograms from the 210^0 Magnetic Meridian on 7 and 10 March 1998.

Discussion

In the event of 10 March 1998 presented in Fig.2 a strong westward auroral electrojet developed under southward IMF Bz. At the same time, the equatorial ionosphere parameters at Cebu and Manila deviated widely from quiet day level. This example suggests that the southward IMF Bz can produce an additional westward current system at the nighttime equatorial ionosphere. This current system can be connected with the Region II FAC intensified during the westward auroral electrojet formation. The mechanism of such a current system formation at the equator in association with the field-aligned currents was proposed as early as in 1908 by Birkeland and then has been further developed. Sizova and Pudovkin (2000) explained the critical frequency foF2 and vertical drift variations during magnetic storms as an effect of the FACs. It was shown that the Region I FACs close across the equatorial ionosphere and enhance the daytime equatorial electrojet. This is the reason of foF2 critical frequency decrease at the equator. According to this view, the foF2 and h'F variations on 10 March 1998 at the nighttime equator can be explained as follows. Electric fields from the Region II FAC penetrate through the midlatitudes to the low-latitude ionosphere and create the additional westward equatorial electric field (Fig. 2, right panel). This electric field increases the nighttime westward equatorial electrojet. In this case, the plasma moves upward away from the F layer, maximum of F2 layer is observed at large heights and one can see foF2 dropping. At the daytime ionosphere at Jicamarca the cause of negative foF2 is the Region I FACs. Since the FACs are in continuous dynamics under the

IMF Bz and By variations, they are responsible for the complicated nature of height and foF2 variations at the equator.

Conclusion

Based on equatorial ionosphere and interplanetary magnetic field data, dynamics of the equatorial ionosphere is investigated. Effect of the IMF Bz on the equatorial virtual heights h'F and critical frequency foF2 is shown. The field-aligned currents as one of the possible sources of this effect are discussed. The equatorial ionosphere dynamics can be followed from the ionospheric characteristics during quiet and disturbed times. Taking into account the time delay between the IMF and ionospheric variations, the IMF observations can be used for predicting equatorial ionosphere characteristics during magnetic storms.

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